BIOBASED BUILDING MATERIALS
Resources for a bright future in housing?

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ABSTRACT: In the housing market enormous challenges exist for the retrofitting of existing housing in combination with the ambition to realize new environmentally friendly and affordable dwellings. Bio-based building materials offer the possibility to use renewable resources in building and construction. The efficient use of bio-based building materials is desirable due to several potential advantages related to environmental and economic aspects e.g. CO_2 fixation and additional value. The potential biodegradability of biomaterials however demands also innovative solutions to avoid e.g. the use of environmental harmful substances. It is essential to use balanced technological solutions, which consider aspects like service life or technical performance as well as environmental aspects. Circular economy and biodiversity also play an important role in these concepts and potential production chains. Other questions arise considering the interaction with other large biomass users e.g. food production. What will be the impact if we use more bio-based building materials with regard to biodiversity and resource availability? Does this create opportunities or risks for the increasing use of bio-based building materials or does intelligent use of biomass in building materials offer the possibility to apply still unused (bio) resources and use them as a carbon sink? Potential routes of intelligent usage of biomass as well as potential risks and disadvantages are highlighted and discussed in relation to resource efficiency and decoupling concept(s).

1 INTRODUCTION

This paper will focus on the developments within the context of the European Union (EU). Several developments are influencing the usage of resources.

1.1 *Increase of population & welfare*

If we do not change the way we use raw materials the amount of resources required is not going to drop on the short term. Since the global world population is still growing, while also the overall global living standards rise an increasing amount of resources will be necessary to meet the global demand. It is estimated that the built environment is responsible for 40% of global energy consumption and about 40% of the waste produced. Additionally the construction industry is using up to 36% of newly extracted resources (SERI, 2009; OECD, 2013). This means that solutions found and implemented in constructions will have a major impact.

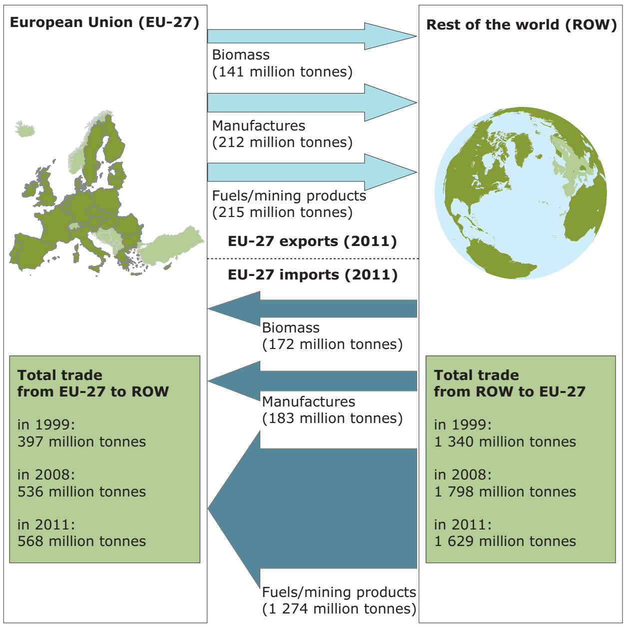

Figure 1. Resource balance for Europe, direct imports and exports of biomass, fuels/mining products and manufactures as well as totals of the EU27 in million tonnes [European Environmental Agency, 2011]

1.2 *Challenges in housing and consequences for resource usage*

In several parts of the world, like China, the challenge is to provide local citizens with healthy and comfortable dwellings that fit their aspirations. This is an enormous task. In the EU the focus is currently on the rejuvenation and renovation projects. When focusing on housing alone this is still an enormous task. In specific regions a decline of the population is complicating this challenging task, since it is unclear in which properties housing associations or other professional investors should invest. The assignment may change if disasters and war force more people to flee their countries and migrate to the more prosperous parts of the world.

New build, rejuvenation and renovation projects increasingly focus on energy efficiency and renewable energy generation. Simultaneously, there is also an increasing interest in sustainable building and resource efficiency issues.

For most governments, economy prevails sustainability issues, since this the economy will affect their voters on the sort term. Sustainability and resource efficiency of course are part of the long-term development. Due to the relatively low commodity prices in the 1990s (VDI, 2008), the availability of resources was not a big issue for companies, their clients and was therefore less discussed in most governments. Since 2003, however, the prices of various raw materials rocketed. This was not only true of steel and crude oil prices, but had in fact turned out to be a general trend (VDI, 2008), as shown by the movements in the Reuters CRB Index. The main reason is that the old rule of thumb – 20% of the world's population in Europe, North America and Japan using up 80% of its natural resources – is no longer valid. Emerging economies such as China and India are now staking claims to these same resources (VDI, 2008). Rising prices allowed resources to be extracted in locations that were previously unprofitable. Companies were also investing more in the exploration of new sites and extraction methods because it has become economically viable to do so.

Recently, several factors, like the economic crisis, fracking and dumping prices of oil, have brought the price of a barrel of oil down. As a result the Reuters CRB Index has come down since the end of 2014. Companies and countries have now experienced how fluctuation in price can hurt their budgets and operational business. This has given a new impulse to rethink their views on resources. Since a long time, we are used to treat natural resources as if they were infinite. Those times now seem to change slowly. Despite that, more is being invested in the extraction of resources in general and methods are constantly being improved. The question arises whether all these efforts are enough to meet the demand for new resources and result in environmental improvements. For example, in 1925, copper ore consisted of 25% copper. By 1985, this percentage had fallen to 0.8% (M2i, 2009). This means that more energy is needed to extract copper and that, at some point, it will no longer be worth making the extra investment.

As some natural resources are extracted in just a handful of places, geopolitical tensions may surface. For example, in 2010 some 95% of the world's scarce earth metals are mined in China (King, 2014) for use in the manufacturing of mobile phones, LEDs, wind turbines, batteries, and computers. Green and clean technologies as for example developed in the US, Japan and Germany are dependent on these scarce earth metals. With demands for virgin resources peaking, production companies depending on the usage of these resources may get into difficulty.

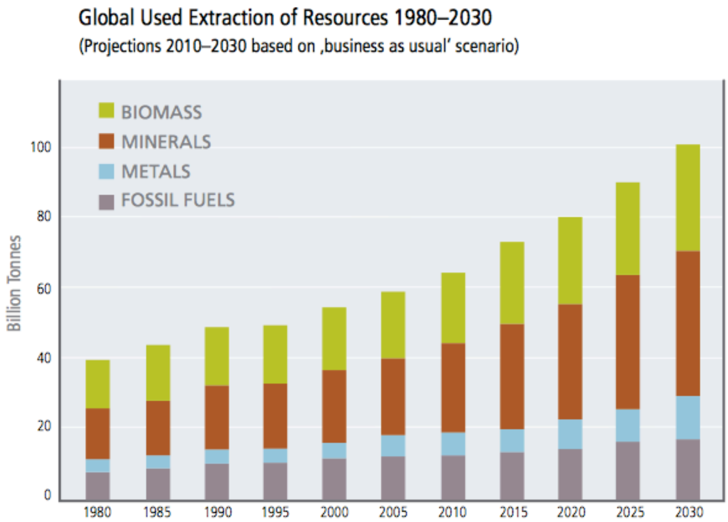

Figure 2. Increasing resource usage [Aachener Stiftung Kathy Beys (eds.), 2011)

1.3 *Increasing demand for bio-based materials*

At the same time there is an increasing demand for bio-based materials with lower environmental impact and with additional functionality. After the economic crisis in Western Europe, the construction and real estate market became more demand-driven. It is now more obvious that sustainable buildings do not only contribute to objectives in the field of responsible social business, but also to technological progress. Sustainable buildings are also more easily rentable, have generally lower operating costs and provide improved comfort, health and productivity (WSBC, 2013). Therefore, the interest for architects, builders and developers is on the increase regarding new quality solutions for the realization of sustainable buildings. Supplying companies realize that they should respond to this, but do not really know how. These companies realize that the development of sustainable products with additional value in comparison to existing alternatives, is no longer a matter of choice, but a necessity (Sailer ea, 2015). For them the urge is caused by increasing competition from lower-wages in other countries and mass production as a result of ongoing globalization. The development of higher quality products, is an obvious way for suppliers to improve competitive advantage. In case of failure, economic shrinkage and substantial job losses might otherwise be the result. The market also feels the pressure of increasing regulation. In the areas of environmental performance or fire safety for example, increasing demands are faced with the consequence that there is hardly any new material available that can meet all requirements when used in building facades. Therefore a number of new building products are applied although they do not meet all requirements arising from existing regulations (Sailer ea, 2015).

Economically it is useful to improve the energy performance of buildings although from a material perspective it can be discussed whether this is desirable. Frequently the relevant conditions are not considered, e.g. material properties besides insulation, availability, fire and safety risks, environmental and biodiversity implications, embedded energy or resource efficiency. Interest in bio-based is on the increase, but it will be impossible to realize the amelioration of building performance with the current amounts of materials available, when constructing or renovating buildings.

2 FROM ENERGY EFFICIENCY TOWARDS RESOURCE EFFICIENCY

As a result of agreements made in Kyoto, COP21 and subsequent agreements made within the EU, or on national or regional levels, the current focus in construction is mainly at CO_2 and energy. Construction authorities and local initiatives are still struggling to translate these agreements into matching market proposals for renewable energy and energy efficiency. As shown in the introduction, also the countries present at the UN Climate Conference in Paris realize that in order to remain within a global temperature rise of 2 or 1.5 degrees, we do not only need an energy transition, but we also need to balance resource usage versus the availability of resources. The Dutch government claims that 25% of CO_2 consumption could be reduced if we would transform towards a circular economy in which everything is recycled and reused. This would additionally lead to a reduction of 25% of the required import of virgin resources (TNO 2013). Although energy is in principle available in abundance, resources are scarce. According to the Global Footprint network we as a species need 1,4 planets to sustain current needs. The average American however has an Ecological Footprint of 9 hectares. A daunting thought since this lifestyle is still appealing to millions all over the globe. If everyone would live like an average US citizen we would need 5 planets. The average in the EU is half, still a 4.5 global hectares per capita. Using the average of people in the UK we would need 3.4 times our planet earth (Global Footprint Network, 2006). And one should realize this number is the sum of the ecological footprint of consumption (for the UK on average 6.1) and the footprint of bio-capacity of the country (for the UK on average 1.6) (Global Footprint Network, 2009).

It is therefore clear we do not only have to put an end to our addiction to fossil fuels for CO_2 reasons. We have to realize resource efficiency in general, hence increasing our efforts to transform towards a circular economy. In the next paragraphs current strategies will be presented to increase resource efficiency.

2.1 *Decoupling*

As a result of fulfilling demands of a growing population that is eager to improve on welfare, more and more resources are deprived from our ecosystems. On the other side disposals and emissions are burdening the natural environment. One of the different concepts to combine economic growth with environmental requirements is the so-called decoupling. This concept tries to combine the reduction of impact to the environment while increasing value created per kilogram at the same time. With this concept the EU is aiming to break the linkage between economic growth, the use of resources and the generation of waste (EU, COM (2001)264). To balance supply and demand, fundamental changes are needed in the way we produce and consume. A lot of struggle is needed in order to get such concepts accepted and applied by the majority of the population, although they are urgently needed.

Worldwide positive signs of decoupling across sectors are measured. According to OECD, the global economy generates 50% more economic value today with one ton of virgin materials than it did in the 1980s, rising from USD 0.70 per kilogram in 1980 to USD 1.05/kg by 2008 (OECD, 2013). Between 1980-2000 materials productivity from 15 EU member states increased form 867 to 1316 euro / tons (2,1% per year), which signifies they got more efficient in deriving value from the resources that were used (Bosmans, 2008). But these numbers are bleak compared to the challenge we are facing.

Dematerialization is a way to decouple and can be accomplished via different routes, for example:

- to use less material for a specific product or function, thereby increasing material efficiency
- to re-use and recycle materials (promoted by concepts as product-as-a-service)
- to share the use of a product among different users (e.g. with the help of online platforms like neighborgoods.net)
- to substitute materials with a highly negative environmental impact by materials with a lower environmental impact (diminishing e.g.: toxicity, energy use during production, weight)

2.2 *Circular material loops across sectors*

Another basic strategy is the development of resource loops for materials of biological and non-biological origin. These loops are not restricted to materials used in the construction sector only. More likely they will be cross-sectorial. And when possible the different fractions available in crops are ideally all used, most likely in different sectors. The introduction of first generation biofuels was followed by criticism on the amount of farmland used for the production of biofuels, displacing food production and increasing food prices. This initiated a quest to combine streams of ingredients from the same crop for different usage.

During the 20th century the amount of resources used globally has grown considerably. At the end of this century we used 34 times more materials, 27 times more minerals, 12 times more fossil fuels and 3,6 times more biomass (UNEP 2011). While resource consumption grew the amount of waste increased as well. In the EU alone total waste generation in EU amounted to approximately 2.5 billion tons in 2013. Only 0.9 billion ton was reused or recycled. This means that 1.6 billion tons were lost for the European economy. It is estimated that at least an additional 600 million tons could be recycled or reused. As is stated in the proposed amendment Directive 2008/98/EC on waste; “The Union thus misses out on significant opportunities to improve resource efficiency and create a more circular economy.” In this proposed amendment, changes where suggested for a number of Directives: Directive 2008/98/EC on waste, Directive 94/62/EC on packaging and packaging waste, Directive 1999/31/EC on the landfill of waste, Directive 2000/53/EC on end-of-life vehicles, Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators and Directive 2012/19/EU on waste electrical and electronic equipment which form part of a Circular Economy Package which also includes a Commission Communication "Closing the loop – An EU action plan for the Circular Economy" (proposal to amend Directive 2008/98/EC on waste).

2.3 *Cascading*

Another concept is to cascade materials before they are incinerated or re-melted. Currently wood and other bio-based materials are used to reduce the CO_2 emissions of energy production. Cascading means that when a component or product faces end of life; e.g. a windowsill, usage is found in another building for the same purpose. Preferable a way for up-cycling is found, or, when the component is down-cycled, usage is chosen in a way which leaves room for numerous reuse options in a next round. Since we generally did not design buildings to be demounted and to be re-used, this approach will change the way future buildings will be designed and constructed. Architects and builders therefore will have to deal with additional requirements. Also building components need to be redesigned in such a way they can be easily re-used and recycled. In case increasing performance requirements and changes of fashion demand rework of the component, the different elements of which the component is made, should also be ready for re-use. In the end it would be logic to limit the use of fossil fuels to the production of high value purposes with no alternative. Companies are looking for alternatives for products currently made from petrol-based virgin materials. Preferably they should be replaced by bio-based alternatives. This ensures that there are alternatives by the time that there are issues with supply or extreme price increases. For industry it is also a way of diminishing dependency, to look for alternative materials of biological origin, so-called renewables or bio-based materials. Examples of products in construction for which fossil fuels are used as a basis for the production: e.g. windowsills, films, insulation materials, ducts, facades finishes, walls and floors.

3 ISSUES IN RELATION TO BIO-BASED BUILDING MATERIALS

3.1 *Advantages*

The advantages presented here will be structured according the Triple Bottom Line (TBL) (Elkington, 1994), also know as the three P's: people, planet and profit. These aspects are most commonly used to evaluate and report on sustainable development (SD) and corporate social responsibility (CSR).

Starting with planet, the environmental perspective, bio-based building materials offer the possibility to use renewable resources in building and construction. The efficient use of bio-based building materials is desirable due to several potential advantages related to environmental and economic aspects e.g. CO_2 fixation. Buildings can be framed as carbon sinks and as materials banks. This will foster to include cascade thinking during the design phase. This is mostly not the case. Also materials outside the actual construction area could be considered. To give an example, clothing of the employees of Aliander, which was no longer in use, was collected as a resource for the insulation material for the new head office in Hoofddorp (Rau, 2016).

Figure 3. Head Office Aliander in Hoofddorp of Thomas Rau [www.rau.eu]

If the bio-based components and materials are reused this will result in a reduction of the use of virgin resources. Energy consumption will be diminished as well as CO_2 emissions. If building components are used in the same region, these achievements can be doubled due to transport savings. This was experienced in two Dutch pilot projects Stadstuin Overtoom in Amsterdam were CO_2 emissions were reduced by 50% and a pilot project in Rotterdam Hoogvliet were CO_2 emissions were reduced by 67% (Cramer, 2013). When local building components and materials are being reused in that same region, the amount of traffic will be diminished. In London transport movements were reduced by 68% with the introduction of a transportation hub for reuse and recycling purposes (Brett, 2007). That is a lot if you realize 30-40% of road traffic is construction related. This will result in a noticeable effect in city centers like London and Amsterdam.

The local economy could benefit from growing the biomass needed and local production of products and components. This could be improved if additionally the reuse and recycling of building components and materials is organized regionally. From the pilot projects in Amsterdam en Rotterdam it became clear that the costs for incineration or disposal can be skipped, as well as the costs otherwise necessary for the purchase of virgin materials. What is needed is extra labor and technology to retrieve the building components from the old building without damaging them. Additionally these components need rework and sorting. The additional costs are somewhere between 10-15% depending on the situation (Cramer, 2013). The assumption is these costs will be reduced when we become more skillful. With experience we will become more efficient in reuse and the flow of reused components and materials will increase allowing economies of scale. BREEAM already developed a demolition directive for the Dutch situation (Cramer, 2013).

A side remark is, that these issues should be looked at from different levels of scale allowing us an overview of the entire value chain. Optimizing one phase, for example, re-use, may mean that e.g. energy consumption during the use phase is increased to such extend, that overall energy consumption worsens. We also should not forget to change perspective. One might have the inclination to start to look at existing buildings from the perspective of a dealer in second hand building products only. Buildings also represent a cultural and historic value that is not easy to capture. A decision to renovate or demolish a building is not simply an economic or environmental question only. Together with other structures buildings form urban fabrics that have their own intrinsic value. Why do we find old city centers appealing? Yet they attract tourist, new citizens and creative professionals. A lesson well learned in the sixties, we should not only look at inner city centers and old neighborhoods from an efficiency perspective in order to structure traffic, high quality dwellings and services.

Finally we arrive at people, the social perspective. People will relearn about local materials and their characteristics. (Re-)working (bio-based) materials will help us to build the necessary circular economy. With the recycling processes new meaningful jobs will be created in the region. Residents of inner cities will also profit from the reduction of traffic, noise, dust and vibration when a regional circular way of working becomes more common.

3.2 *Risks and other important aspects*

An important aspect of biomaterials is the technical service life. In order to extend the service life, biomaterials need to be protected against degradation by e.g. UV-radiation or micro-organisms. These degradation factors frequently cause higher maintenance costs and limit the functionality and influence the aesthetics of building skins. Adequate sustainable solutions are therefore wanted especially since the use of toxic substances (biocides) is increasingly restricted by legal regulations (Directive 98/8/EC). In coatings heavy metals may no longer be used. Most countries prevent the use of CCA (copper-chromium-arsenic) and the use of impregnated wood is more and more restricted (Kwon et al, 2004). Because there are (still) not enough sufficient sustainable and competitive solutions, the use of indigenous renewable resources such as wood is still limited. Without technically and economically viable alternatives the ambitions have to be adapted to the technological available possibilities. This happens despite the fact that different governments are trying to encourage the use of sustainably produced materials (EU commission, 2011). The potential biodegradability of biomaterials however also demands innovative solutions to avoid e.g. the use of environmental harmful substances in buildings. It is essential to use balanced technological solutions, which consider aspects like service life or technical performance as well as environmental aspects.

Circular economy and biodiversity also play an important role in these concepts and potential production chains. Questions arise considering the interaction with other large biomass users e.g. food production. What will be the impact with regard to biodiversity and resource availability, if we use more bio-based building materials?

Does this create opportunities or risks for the increasing use of bio-based building materials or does intelligent use of biomass in building materials offer the possibility to apply still unused (bio) resources and use them as a carbon sink?

4 STRATEGIES TO INCREASE THE USAGE OF BIO-BASED BUILDING MATERIALS

As is stated in the Ellen MacArthur Foundation report (2013), implementation of sustainability measures are helped by collective goals. From what is known in the domain of transition management and what is learned from the quest on how to implement and upscale energy efficiency in the Netherlands and other innovations in Finish construction, it is known that strategies should be addressing the following three aspects when aiming at step change innovation (Oostra & Huovinen, 2016):

Goal setting – it has proven to be very helpful if a mutual goal is set among a group of stakeholders that are able to make the change. Key public decision making bodies, at a governmental, regional and or city level, or an organization that is representing the general interest, define clear goals in conjunction with key stakeholders, daring to be frontrunners. “These goals are set (1a) to improve outcomes on each of the socio-political, economic, institutional, technological and environmental contexts, (1b) to unite stakeholders in terms of balancing their aims and benefits, (1c) to stimulate the sector to include other (only value adding) stakeholder groups in order to be able to reach goals and overcome barriers to be met, and (1d) not to be afraid of asking for radical innovations on key dimensions” (Oostra & Huovinen 2016). Usually the programme starts with small-scale pilot projects to make visible that the goals are actually achievable and to reassess the goals before the programme actually starts.

Network formation – example programmes show that a range of networks needs to be formed in which (2a) new key roles can emerge for stakeholders, (2b) connecting multi-dimensional, causal links between different stakeholder/party roles to fine-tune issues. Space is left to introduce novel expertise and insightful stakeholders when new issues pop up during the developments. Memberships are expanded through the different phases of the programme. While there should remain some space to exchange things without spotlights, e.g. think out new innovations, key decisions, activities and tasks will be made transparent for others to learn from, to analyze and to evaluate. The programme should be able to tune itself along the way. All sorts of institutional, digital and physical supportive systems will need to be developed as well, as well as tools that parties can rely upon (Oostra & Huovinen 2016).

Learning – To enhance learning, “a range of alternative ways of learning, exploiting existing knowledge and creating new solutions, be selected and planned by learning areas, to arrive at: (3a) a flexible, highly sustainable market and better knowledge of user preferences in relation to changing demographics, public, private and third sectors, built environment, nature, etc., (3b) product and process innovations, incremental/disruptive, solo/co-innovated, co-funded, given/openly competed, scaled up/down, etc., (3c) new rules and regulations to mend hampering or missing legislation, on city/country/EU levels, by areas and units, etc., (3d) affordable prices, performance improvements and guarantees for stakeholder groups and participant roles, home/apartment/house types, public and private buildings, infrastructure, etc., (3e) improvement of architectural quality, environmental quality and building quality to enhance the realization of appealing cities, attractive country-sides, meaningful places, true well-being, environmental sustainability, personalized living, inclusive society, regional prosperity, etc. and (3f) commitment from stakeholders to take on new roles and responsibilities designated to realize the goals set and provide performance warranties. The members of the programme compare the alternative routes, choose the most effective ones and integrate them accordingly in designated sub-programmes to start the next learning cycle." (Oostra & Huovinen, 2016).

5 CONCLUSION

As shown before, the broad implementation of biomaterials for housing is a complex field with many different factors to be considered. Although huge political efforts are made, the realization within still relative traditional production and implementation chains like those from the building industry is complicated. The technological progress and competiveness have to be faster improved otherwise bio-based materials will probably not get a serious market position compared to traditional products with more negative environmental impact. If decoupling and cascading concepts succeed with more technological, environmental and economic impact a broader implementation of bio-based materials can be achieved. Circular economy concepts as well as creative implementation strategies are a prerequisite to realize the ambitions and overcome the existing challenges to build socially, economically and environmentally acceptable buildings.

6 REFERENCES

Aachener Stiftung Kathy Beys (eds.) (2011) *Factsheet Measuring Resources Extraction Communication* From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions Innovating For Sustainable Growth: A Bioeconomy For Europe 2012

Bosman, W. (2008) *EU-Thematic strategy on the sustainable use of natural resources: Environmental problems in Asia from the perspective of material flows; towards sound material-cycle society for East Asia*, European Commission DG Environment – G4, presentation

Brett, P. (2007). Construction Consolidation Centres; An Assessment of the Potential for London wide use. Project Ref: 17321/004, May, 2007

Cramer, J. (2013) van Cirkelstad naar Cirkelland, Hergebruik van Bouw- en Sloopafval loont! Handreiking voor woningcorporaties, publication Cirkelstad

COM(2001)264 (2001) A Sustainable Europe for a Better World: A European Union Strategy for Sustainable Development, Brussels, 15.5.2001, COMMUNICATION FROM THE COMMISSION

Directive 1999/31/EC on the landfill of waste,

Directive 2000/53/EC on end-of-life vehicles,

Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators

Directive 2008/98/EC on waste

Directive 2012/19/EU (2012) waste electrical and electronic equipment (WEEE), 4 July 2012.

Directive 94/62/EC on packaging and packaging waste,

Directive 98/8/EC of the European Parliament and of the Council of 16 February 1998 concerning the placing of biocidal products on the market

Elkington, J. (1994), "Towards the sustainable corporation: Win-win-win business strategies for sustainable development", *California Management Review*, Vol. 36, issue 2: 90-100

Ellen MacArthur Foundation (2013) *Towards the circular economy; Opportunities for the consumer goods sector*

European Environmental Agency (2011) *EU-27 physical trade balance with the rest of the world*, downloaded from www.eea.europa.eu September 25th, 2016.

European Commission (2011) Communication From the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, *A re-*

source-efficient Europe – Flagship initiative under the Europe 2020 Strategy
Global Footprint Network, (2009) *National Footprint Accounts 2009 data tables (hectares),* retrieved on September 20th, 2016 from http://www.footprintnetwork.org/
Global Footprint Network, (2010) *Ecological Footprint Atlas 2010*, authors: Ewing B., D. Moore, S. Goldfinger, A. Oursler, A. Reed, and M. Wackernagel, retrieved on September 20th, 2016 from http://www.footprintnetwork.org/
King, H. (2014) REE – *Rare Earth Elements and their Uses*; The demand for rare earth elements has grown rapidly, but their occurrence in minable deposits is limited. retrieved on September 25th, www.geology.com
Kwon, Elena, Hongquan Zhang, Zhongwen Wang, Gian S. Jhangri, Xiufen Lu, Nelson Fok, Stephan Gabos (2004) Arsenic on the Hands of Children after Playing in Playgrounds, 3. Number 14, s.l. : *Environmental Health Perspectives*, Volume 112, p. 1375-1380.
M2i (2009), *Material Scarcity; an M2i study*, authors: Huib Wouters & Derk Bol, Delft, November 2009.
OECD (2013), *Material Resources, Productivity and the Environment; keyfindings*, retrieved on September 20th, 2016 from http://www.oecd.org/
Oostra, M.A.R. & Huovinen (2016), Radical Programmes for Developing the EU Residential Building Sector, *CIB World Building Congress 2016 Intelligent built environment for life*, vol. I, Creating built environments of new opportunities, Helsinki.
Rau, T. (2016), From optimization to transformation, keynote lecture *SBE16 conference Transition Zero*, Utrecht the Netherlands, April 8th, 2016.
Sailer, M. & M.A.R. Oostra (2015) *Polypyrrol; adding smart functions to biobased facades,* RAAK proposal, Saxion, March 2015
SERI (2009), *Overconsumption? Our use of the world's natural resources*. SERI, GLOBAL 2000, Friends of the Earth Europe, September 2009, 36 pp.
TNO (2013) *Kansen voor een circulaire economie*, report
UNEP (2011) *Decoupling natural resource use and environmentsl impacts from economic growth*, United Nations Environment Programme, lead author Marina Fischer-Kowalski
VDI (2008), *Innovationen gegen Rohstoffknappheid*, authors: Günther Reusscher, Christiane Ploetz, Vera Grimm & Axel Zweck, Zukünftige Technologien Consulting on assignment of VDI, Düsseldorf 2008.
WGBC (2013), *The Business Case for Green Building; A review of the costs and benefits for developers, investors and occupants*, - World Green Building Council, www.worldgbc.org.